fermentation

MDPI

Editorial

Anaerobic Digestion of Food Waste: New Research, Challenges and Opportunities

Grazia Policastro [1,*] and Massimiliano Fabbricino [2]

[1] Telematic University Pegaso, 80100 Naples, Italy
[2] Department of Civil, Architectural and Environmental Engineering, University of Naples Federico II, 80125 Naples, Italy
* Correspondence: grazia.policastro@unipegaso.it

Every year, about one-third of food is wasted through the food supply chain, generating many economic, environmental and social issues. Meanwhile, the increasing global energy demand and depletion of fossil fuels are driving international policies to promote the use of alternative energy sources. In this regard, the recovery of energy from food waste not only constitutes an economic opportunity, but could also contribute to the mitigation of greenhouse gas (GHG) emissions and improvements in food waste management. Biological processes represent a valuable option for the environmentally-friendly treatment of the mentioned streams [1]. In this Special Issue, the sustainability of biological treatments for food waste has been studied by Thapa et al. [2]. The authors used the average composting data for Canada in order to determine the change in carbon footprint caused by the diversion of food waste. It was determined that the overall carbon footprint was remarkably reduced from the composting of food waste, confirming the environmental effectiveness of biological treatments [2].

Among biological processes, anaerobic digestion (AD) is one the most suitable technologies for stabilizing organic wastes, due to its limited environmental impacts and high potential for energy recovery. On the other hand, although AD is consolidated and widely applied, it still faces a number of technical and economic challenges [1]. Therefore, further efforts are required to effectively improve the AD process from food waste. In this Special Issue, different aspects have been studied: the optimization of the technology from both the biological point of view [3] and the reactor configuration [4], as well as problems related to the digestate management [5].

For instance, Mazzurco Miritana et al. applied the bioaugmentation strategy to improve the AD of shrimp processing waste (SPW). The authors used a fermenting bacteria pool (F210) and two strains of anaerobic fungi (AF). They tested both the single and combined bioaugmentation at different SPW concentrations. The results showed that cumulative methane productions were optimized by the combined bioaugmentation strategy and that they increased with SPW concentration. Moreover, the F210 pool played a key role in the process optimization, whilst no effect was obtained via the addition of AFs [3].

Parajuli et al. studied the reactor configuration by the optimization of the hydraulic retention time (HRT) and organic loading rate (OLR) of a two-stage semi continuous reactor, fed with food waste. The results showed that the reduction in the HRT and the increase in the OLR in the first stage led to a methane decrease from 18.20% to 0.06%, thus fostering hydrogen production. At the steady state, the optimized system produced 22.32 ± 4.16 NmL/gVS of hydrogen in the first stage and 161.02 ± 17.72 NmL/gVS of methane in the second stage [4].

Regarding the management of the AD effluent (i.e., digestate), it is well known that sometimes its characteristics (e.g., high ammonia concentration and/or presence of dangerous compounds) may represent a challenge [6].

Citation: Policastro, G.; Fabbricino, M. Anaerobic Digestion of Food Waste: New Research, Challenges and Opportunities. *Fermentation* **2023**, *9*, 473. https://doi.org/10.3390/fermentation9050473

Received: 6 May 2023
Accepted: 11 May 2023
Published: 15 May 2023

For instance, the presence of contaminants, including petroleum hydrocarbons, could limit the widespread agricultural utilization of digestate. In this context, De Simone et al. elucidated the effect of cationic polyelectrolyte addition on biomethanation as well as the degradation and extractability of C_{10}–C_{40} hydrocarbons during the mesophilic AD of contaminated sewage sludge. The results showed that the addition of cationic polyelectrolyte extended the AD lag phase. Nonetheless, the methane yield was not affected, concomitantly leading to a significant impact on hydrocarbon degradation [5].

Over the last decade, a novel modification of the AD process called dark fermentation (DF) has gained increasing attention, due to its capability to convert organic waste into valuable organic compounds (i.e., organic acids and alcohols) and energy (i.e., hydrogen) [7]. The possibility of producing hydrogen instead of methane makes DF a suitable and environmentally-friendly process. Indeed, hydrogen is a viable alternative energy carrier because of its stability, high energy content and lack of greenhouse gas emissions [8]. On the other hand, different DF issues such as the problems related to substrate characteristics and the low hydrogen yields need to be solved. In the SI, different solutions aimed at improving the DF process have been proposed, including the co-substrate fermentation strategy [9] and the coupling of DF with further processes [10,11].

For instance, Policastro et al. investigated the inhibiting effect of two problematic biomasses (i.e., of olive mill wastewater, containing recalcitrant/toxic compounds and cheese whey, lacking pH buffering capacity). The authors studied the possibility of applying a co-fermentation strategy to enhance the process. The obtained results confirmed that the two investigated substrates exerted inhibiting effects on microorganisms when used alone. Nevertheless, the use of 20% cheese whey and 80% olive mill wastewater allowed the authors to double the hydrogen yield [9].

During DF, hydrogen is produced together with organic acids (OAs) and alcohols, leading to low hydrogen yields. To improve these yields, the coupling of DF and PF processes allows for the assimilation of the OAs produced during the DF in the PF; this leads to greater hydrogen production from the substrate. In this context, mixed phototrophic cultures represent better alternatives compared to pure ones [12]. Gonzalez et al. studied microbial interactions in natural and synthetic consortia and investigated the bioaugmentation strategy to improve the performance of the photo fermentation processes. The results confirmed that the use of a consortium of *Clostridium pasteurianum*, *Rhodopseudomonas palustris* and *Syntrophomonas wolfei* enhanced hydrogen production. A further improvement was observed when *S. wolfei* was added as the bioaugmentation agent [11].

Finally, Zonfa et al. investigated a two-stage process for cheese whey valorization by integrating DF with an electrochemical system, with the aim of overcoming the thermodynamic/biochemical limitations of fermentation and enhancing hydrogen recovery. The bio-electrochemical process achieved promising results, displaying a three-times higher hydrogen production yield compared to the conventional dark fermentation method [10].

To summarize, in this Special Issue, the authors faced different challenges related to many aspects of the process and proposed many innovative solutions, providing interesting research results and perspectives in relation to the AD of FW.

Funding: This research received no external funding.

Acknowledgments: The editors thank all authors and editorial staff who contributed to the success of this Special Issue.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Xu, F.; Li, Y.; Ge, X.; Yang, L.; Li, Y. Anaerobic Digestion of Food Waste—Challenges and Opportunities. *Bioresour. Technol.* **2018**, *247*, 1047–1058. [CrossRef] [PubMed]
2. Thapa, P.; Hasnine, M.T.; Zoungrana, A.; Thakur, S.; Yuan, Q. Food Waste Treatments and the Impact of Composting on Carbon Footprint in Canada. *Fermentation* **2022**, *8*, 566. [CrossRef]

3. Mazzurco Miritana, V.; Gaetani, A.; Signorini, A.; Marone, A.; Massini, G. Bioaugmentation Strategies for Enhancing Methane Production from Shrimp Processing Waste through Anaerobic Digestion. *Fermentation* **2023**, *9*, 401. [CrossRef]
4. Parajuli, A.; Khadka, A.; Sapkota, L.; Ghimire, A. Effect of Hydraulic Retention Time and Organic-Loading Rate on Two-Staged, Semi-Continuous Mesophilic Anaerobic Digestion of Food Waste during Start-Up. *Fermentation* **2022**, *8*, 620. [CrossRef]
5. De Simone, S.; Di Capua, F.; Pontoni, L.; Giordano, A.; Esposito, G. Impact of Cationic Polyelectrolyte Addition on Mesophilic Anaerobic Digestion and Hydrocarbon Content of Sewage Sludge. *Fermentation* **2022**, *8*, 548. [CrossRef]
6. Policastro, G.; Cesaro, A.; Fabbricino, M.; Pirozzi, F. Opportunities and Challenges from Symbiosis of Agro-Industrial Residue Anaerobic Digestion with Microalgae Cultivation. *Sustainability* **2022**, *14*, 15607. [CrossRef]
7. Ghimire, A.; Frunzo, L.; Pirozzi, F.; Trably, E.; Escudie, R.; Lens, P.N.L.; Esposito, G. A Review on Dark Fermentative Biohydrogen Production from Organic Biomass: Process Parameters and Use of by-Products. *Appl. Energy* **2015**, *144*, 73–95. [CrossRef]
8. Muscetta, M.; Clarizia, L.; Race, M.; Andreozzi, R.; Marotta, R.; Di Somma, I. Visible—Light Driven Systems: Effect of the Parameters Affecting Hydrogen Production through Photoreforming of Organics in Presence of Cu_2O/TiO_2 Nanocomposite Photocatalyst. *Appl. Sci.* **2023**, *13*, 2337. [CrossRef]
9. Policastro, G.; Lamboglia, R.; Fabbricino, M.; Pirozzi, F. Enhancing Dark Fermentative Hydrogen Production from Problematic Substrates via the Co-Fermentation Strategy. *Fermentation* **2022**, *8*, 706. [CrossRef]
10. Zonfa, T.; Kamperidis, T.; Falzarano, M.; Lyberatos, G.; Polettini, A.; Pomi, R.; Rossi, A.; Tremouli, A. Two-Stage Process for Energy Valorization of Cheese Whey through Bio-Electrochemical Hydrogen Production Coupled with Microbial Fuel Cell. *Fermentation* **2023**, *9*, 306. [CrossRef]
11. González, A.; Salgado, E.; Vanegas, Z.; Niño-Navarro, C.; Cortés, O.; Chairez, I.; García-Peña, E.I. Simultaneous Production of Biohydrogen (BioH2) and Poly-Hydroxy-Alkanoates (PHAs) by a Photoheterotrophic Consortium Bioaugmented with Syntrophomonas Wolfei. *Fermentation* **2022**, *8*, 644. [CrossRef]
12. Policastro, G.; Carraturo, F.; Compagnone, M.; Guida, M.; Fabbricino, M. Enhancing Hydrogen Production from Winery Wastewater through Fermentative Microbial Culture Selection. *Bioresour. Technol. Rep.* **2022**, *19*, 101196. [CrossRef]